

SUMMARY OF ALTERATIONS BY HUMAN ACTIVITY AND CUMULATIVE IMPACTS

The objective of this portion of the Technical Report to the Ocean Management Task Force is to summarize and describe the major human-induced and natural impacts to estuarine and marine habitat and life. A thorough environmental assessment of cause and effects associated with the abundance of discrete human-induced impacts and natural processes or a comprehensive review of cumulative impacts is a complex issue and is beyond the scope of this report. Rather than a “cumulative impacts assessment”, this report briefly explains cumulative impacts, describes major anthropogenic impacts and natural influences, lists Massachusetts examples of these impacts, shows the geographic location of key impacts, and presents emerging issues.

EXPLANATION OF CUMULATIVE IMPACTS

Alteration of estuarine and marine habitat and life by human activity – combined with impacts from naturally occurring environmental variation – leads to cumulative impacts to all sectors of the marine environment. Vestal et al. (1995) describes cumulative impacts as the combined outcome of numerous actions and stresses, where a group of relatively minor and major impacts may add up to severe habitat degradation or loss. This view is also shared by the Environmental Protection Agency, which asserts that cumulative impacts accumulate over time, from one or more sources, and can result in the degradation of important natural resources (EPA 1999).

According to The Council on Environmental Quality/National Environmental Policy Act regulations (40 CFR §§ 1500 -1508), and for the purposes of this report, we define “direct effects”, “indirect effects” and “cumulative impacts” as follows:

- **Direct effects** are caused by the action and occur at the same time and place. (40 CFR § 1508.8)
- **Indirect effects** are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems. (40 CFR § 1508.8)
- **Cumulative impact** is the impact on the environment, which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. (40 CFR § 1508.7)

Additive effects and synergism are important topics to discuss while describing cumulative impacts but are different from cumulative impacts. Additive effects are the combined consequence of independent, multiple impacts; synergistic interactions are a more complex magnification of threats to produce a greater impact than additive effects.

That is, the combined toxicity of two contaminants is (can be) greater (synergism) than their combined, independent toxicities (additive effects). These terms are frequently used while discussing multiple environmental impacts.

Cumulative impacts include additive and synergistic impacts and encompass wide-ranging ecological implications of human perturbation and natural patterns of variability. For example, the alteration of habitat and biological communities through the degradation of water quality due to point and nonpoint sources of pollution, high rates of organic loading to seafloor habitats as a result of watershed changes and increased run-off, and changes to species assemblages due to commercial exploitation leads to substantial loss to habitat and associated communities both spatially and temporally on a broad scale.

Because cumulative impacts affect a wide range of estuarine and marine habitats and all species (either directly or indirectly), they should be considered when developing ocean resources management strategies. However, it is difficult to achieve a clear understanding of the cumulative effects of human activities; specifically, separating human induced impacts from natural variation is a challenging but not impossible task (i.e., the cause and effect of many anthropogenic impacts are understood). Long-term systematic monitoring and targeted research are required to understand variability in natural resources and anthropogenic influences to natural resources. The status of ocean resources and the understanding of human-induced impact on ocean resources will remain difficult to understand without a substantial investment in monitoring and research.

While it is on occasion difficult to distinguish between human induced changes and natural variation, it is a well-known fact that anthropogenic changes contributed to extensive environmental stress in the Massachusetts marine environment. Regional efforts are ongoing to coordinate monitoring efforts, and Massachusetts should play a key role in developing monitoring and research plans and include efforts to understand cumulative impacts (CICEET 1999; cited in Concept Paper: Aquatic Habitats Northeast Indicators Workshop, January 6-8, 2004; Krahforst personal communication).

HUMAN-INDUCED IMPACTS AND NATURAL PROCESSES OF OCEAN RESOURCES

Increasing human population, particularly the coastal population, is the root of the majority of human-induced impacts. The northeastern United States (from Maine to Maryland) currently accounts for about one third of the nation's coastal population, and 16% of the entire national population (Culliton et al. 1990). In the year 2000, 34% of the total Massachusetts population lived along the coast, demonstrating the extent of development along Massachusetts coastline. Please refer to human population section of 'Trends in the Demographics of Human Population and the Massachusetts Marine Economy' for a breakdown of the coastal population by county and town.

The demands of a high-density coastal population place a significant burden on coastal and ocean resources. For example, humans require wastewater treatment facilities and

the associated disturbances have ecological consequences that extend to nearshore and offshore systems. There are many human uses of Massachusetts waters, and often these uses are conflicting; these uses should also be considered when examining human induced impacts (refer to 'Characterization of the Ocean Uses').

Summary of the Types of Human-Induced Impacts and Natural Processes in Massachusetts

Human-induced impacts and natural processes do not equally affect all resources and regions. Human-induced threats/impacts are both direct and indirect in nature. As seen in Table 1, direct human impacts from activities like dredging, siting of power plants and commercial fishing each have immediate impacts to the marine environment. Indirect human impacts include nonpoint source pollution and watershed development. Many of these activities may occur in coastal waters and contribute pollutants to the coastal zone, but their impacts, (like runoff of pollutants such as pesticides, herbicides and nutrients) are diffused over wide areas. Both direct and indirect human impacts cause environmental effects that are cumulative in nature.

There are many human-induced impacts, or sources of potential adverse impact, throughout Massachusetts waters. Table 1 shows major impacts, divided by type of anthropogenic impact (direct or indirect). Naturally occurring threats also influence ocean resources. Table 2 identifies global threats, divided by type of impact (natural disturbance and global climate change). Tables 1 and 2 list the geographic distribution of each type of impact. For the purposes of this section the following descriptions are applied:

- *Geographic distribution in Massachusetts* is a general representation of how these impacts are distributed along the state's coast and offshore waters. While the environmental effects of a particular threat or adverse impact may not necessarily be "widespread", "moderate" or "minimal", the following table illustrates the expanse of the impacts of the activity. For example, power plants are not present in all coastal areas, but power plants have wide-ranging impacts to many ecological functions. While a detailed illustration of the temporal and spatial scale or proportion of these impacts is not described, it is important to remember that several small-scale projects and broad environmental alterations result in a large cumulative impact. Additionally, sources of identified impacts may be more prevalent in certain areas as different parts of the coastline are only suitable for certain projects (e.g., shellfish aquaculture in Cape Cod Bay).
- *Coastal & offshore construction/shoreline armoring* (under direct impacts) includes any building and/or erosion control barriers in the shoreline, nearshore or offshore areas (e.g., dock and pier construction, proposed windmill energy projects, and fish pens for aquaculture), while *watershed development* (under indirect human impacts) is meant to include all landscape alteration and construction in coastal watershed areas located upland. These two categories are not always discrete.

Table 1. List of types of human-induced impacts that affect ocean resources in Massachusetts (adapted from Wilbur and Pentony (1999); Concept Paper: Aquatic Habitats Northeast Indicators Workshop, January 6-8, 2004).

TYPE OF IMPACT	GEOGRAPHIC DISTRIBUTION IN MASSACHUSETTS			
	Widespread	Moderate	Minimal	Unknown
DIRECT HUMAN				
Coastal & offshore construction/ shoreline armoring				
Filling				
Dredging				
Dredged material disposal				
Sand mining				
Damming				
Pipelines/cables construction				
Sewage treatment plants				
Power plants				
Industrial discharge/outfalls				
Commercial fishing/harvest				
Shellfish aquaculture				
Recreational boating				
Marine/ferry transportation				
INDIRECT HUMAN				
Watershed development				
Nonpoint source pollution				
Air pollution				
Boat fuel and wastes				
Ballast-water discharge				
Oil/toxic spills				
Algae blooms				
Disease				
Invasive species				

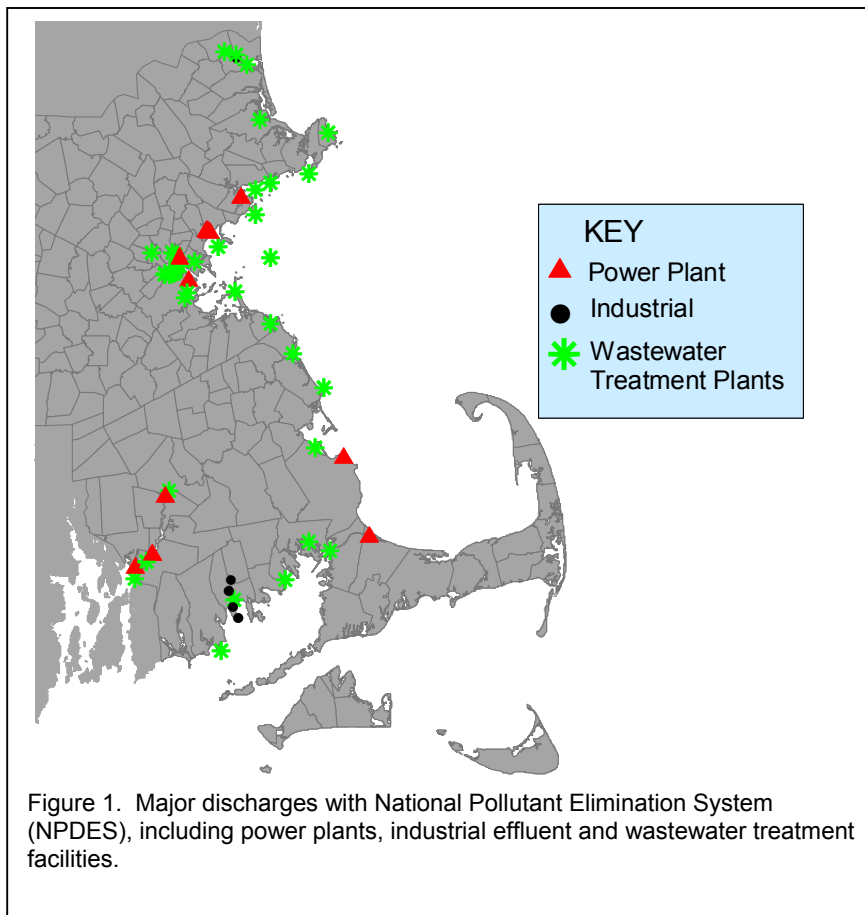
Natural processes include natural disturbances and global climate change, but these global phenomena are often influenced by human activities (e.g., contribution of greenhouse gases to the atmosphere increase rates of global climate change). The geographic effects of these processes are largely unknown, as are the long-term environmental consequences, although they are assumed to be pervasive and far-reaching. Substantial volumes of science are beginning to demonstrate the ecological consequences of these large-scale processes (through space and time); ‘Oceanography, Weather Patterns, and Climate Change’ provides a summary of climate change and weather patterns.

Table 2: List of regional/global processes affecting Massachusetts ocean resources. Note: impacts associated with natural disturbance and global climate change are often exacerbated by human activities.

TYPE OF IMPACT	GEOGRAPHIC DISTRIBUTION IN MASSACHUSETTS			
	Widespread	Moderate	Minimal	Unknown
NATURAL DISTURBANCE				
Storms				
Climatic processes				
Biotic processes				
GLOBAL CLIMATE CHANGE				
Accelerated sea-level rise				
Ocean warming				
Atmospheric ozone depletion				

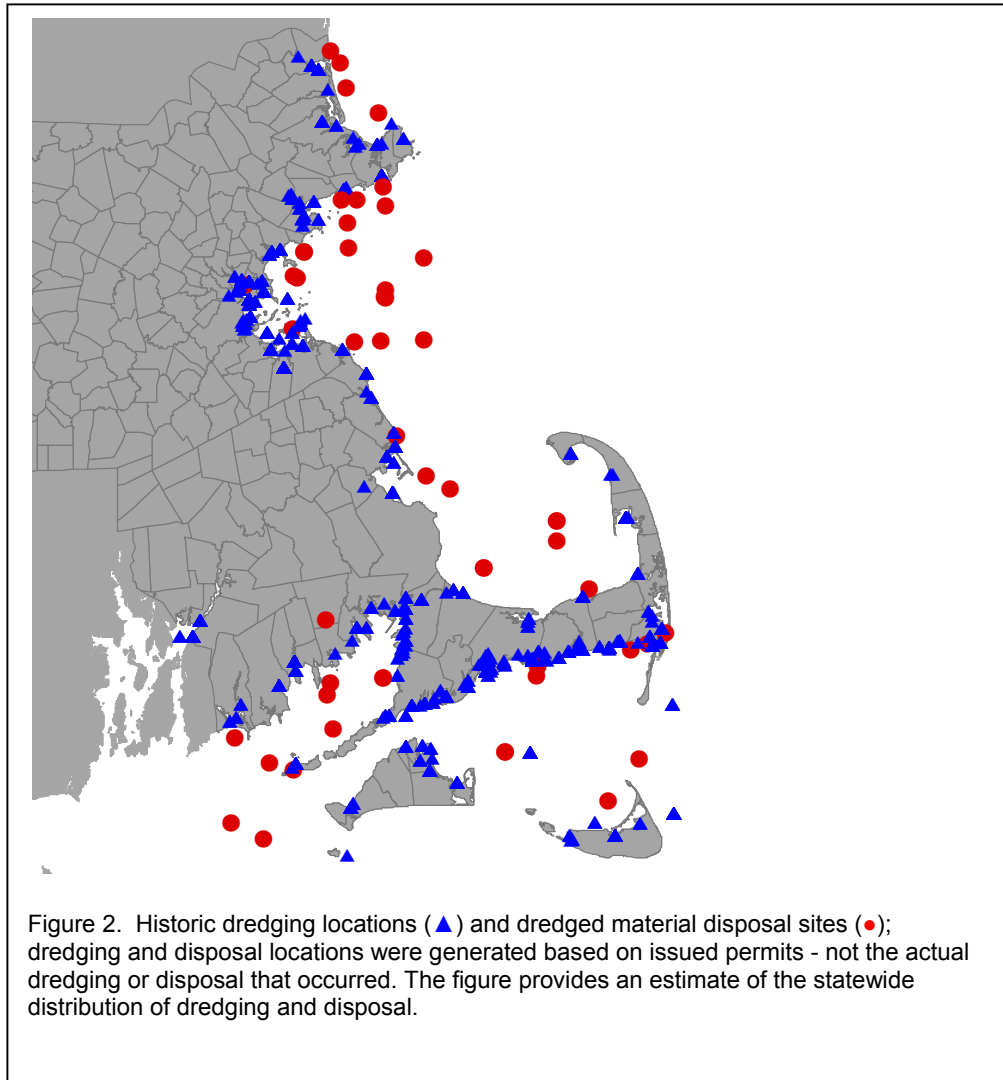
DISTRIBUTION OF CUMULATIVE IMPACTS

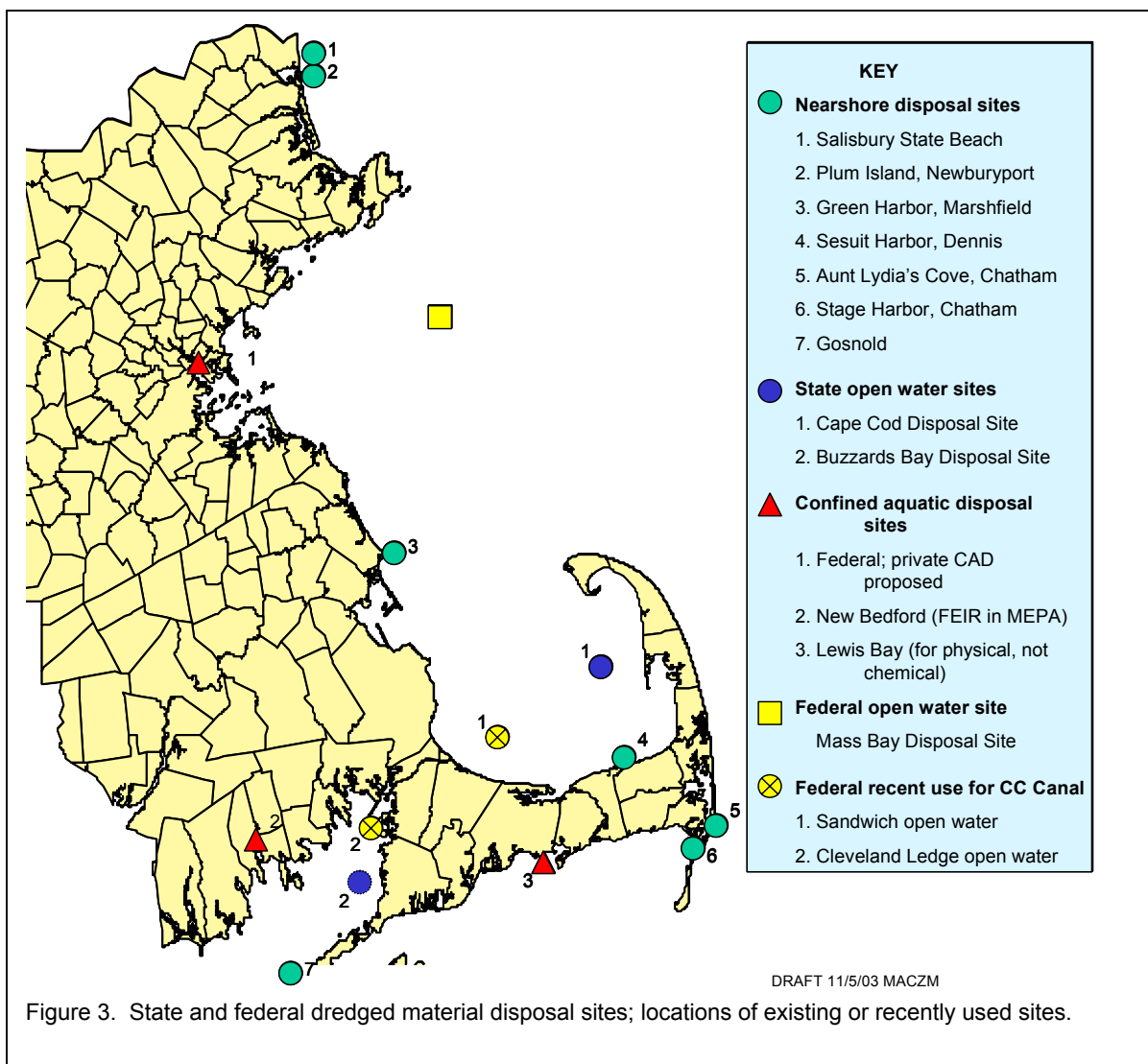
An example of the result of cumulative impacts is seen through changes in water quality over time. Direct human impacts along the Massachusetts coast, like construction of industrial discharge/outfalls (Figure 1), dredging and dredged material disposal (Figure 2



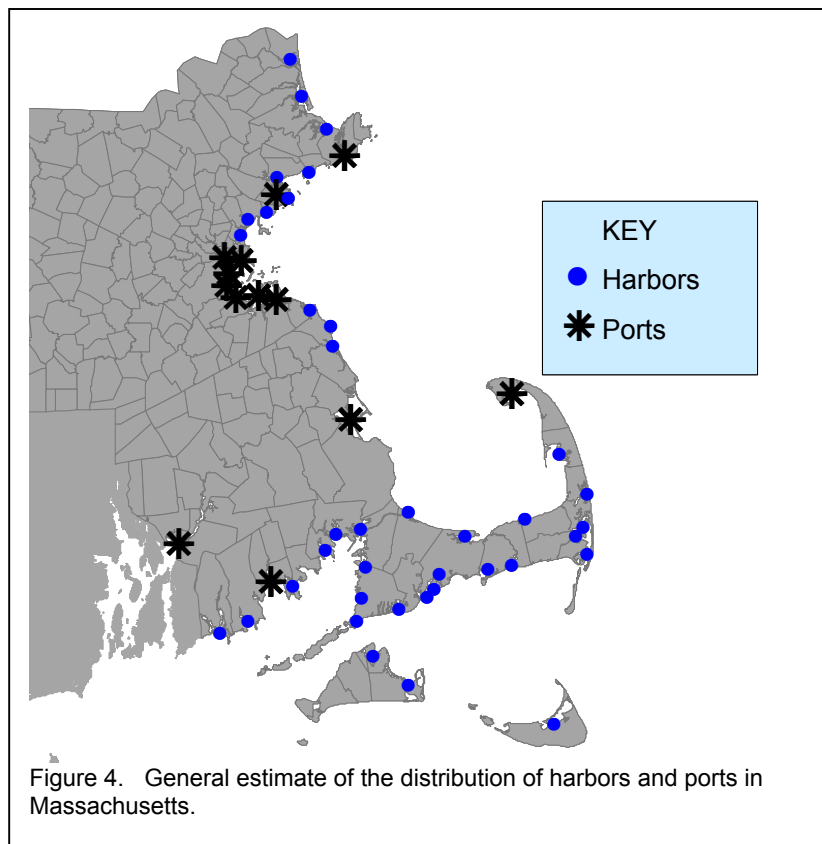
and Figure 3), when combined with indirect human impacts like watershed alteration and nonpoint source pollution (chemical agricultural runoff, including pesticides and herbicides, and stormwater runoff), and oil/toxic spills, have significant effects on the environmental quality of Massachusetts over time. This is a brief example of the extent and type of major impacts to the ocean resources in Massachusetts. The impacts identified in Table 1 and 2 and shown in the figures

represent individual activities that affect ocean resources; the tables and figures do not describe ecological consequences of these impacts and activities.





When considering the geographic distribution of environmental impacts, the recreational boating industry provides a good example. There are 270 recreational marinas along the Massachusetts coast, with most having 50 slips or more each in the year 2000 (Lacey,



personal communication). The distribution of harbors and ports (Figure 4) provides a generic estimate of areas heavily used by recreational boaters and also shows the location of industrial vessel activity. Recreational boating activities from these marinas (including additional boats using marinas for daily access) potentially stress the marine and coastal environment and present a number of dangers. A gathering of vessels leads to a higher potential and

concentration of toxic spills, including fuel, paint, chemical solutions to remove fouling organisms and other cleaning materials. Recreational vessels also contribute to direct habitat degradation (e.g., seagrass scarring from propellers, anchors and moorings) and overall noise pollution from motor activity. In addition, marina infrastructure such as floating docks, buoys and pilings offers opportunities for invasive species attachment and alter environmental conditions.

While recreational marinas are located along the entire coast, most of the individual towns that have five or more recreational marinas are in southern Massachusetts, including Buzzards Bay, Edgartown, Falmouth, Hyannis, New Bedford, Fairhaven and Vineyard Haven. In addition to the recreational boating, there is already wastewater treatment, harbor development, and dredging and disposal in these areas. Newburyport (10 marinas), Gloucester (12 marinas), and Falmouth (13 marinas) also have substantial numbers of marinas for individual municipalities.

CUMULATIVE IMPACT EXAMPLE: BOSTON HARBOR

The density of harbor and port construction reflects a highly populated coastal area, namely in the Boston Harbor area (Figure 4). Human induced impacts are more heavily

concentrated in Boston Harbor than in other areas along the Massachusetts coast. Johnson and Rodrigues (2004) developed three maps to illustrate impacts in the area. The extent and type of environmental impacts in Boston Harbor serve as an example of the abundance and diversity of human influences that affect ocean resources.

When considering human impacts, it is important to remain conscious of the marine and coastal habitats that continue to be threatened (Figure 5). Despite the progress of the Boston Harbor cleanup, there are still many environmental issues to address. There are several hazardous waste sites (including sites of Superfund National Priority) and an influx of point source pollution concentrated around the harbor (Figure 6). In addition, direct impacts from activities such as dredging and dredged material disposal and coastal and underwater construction continue to affect the area (Figure 7).

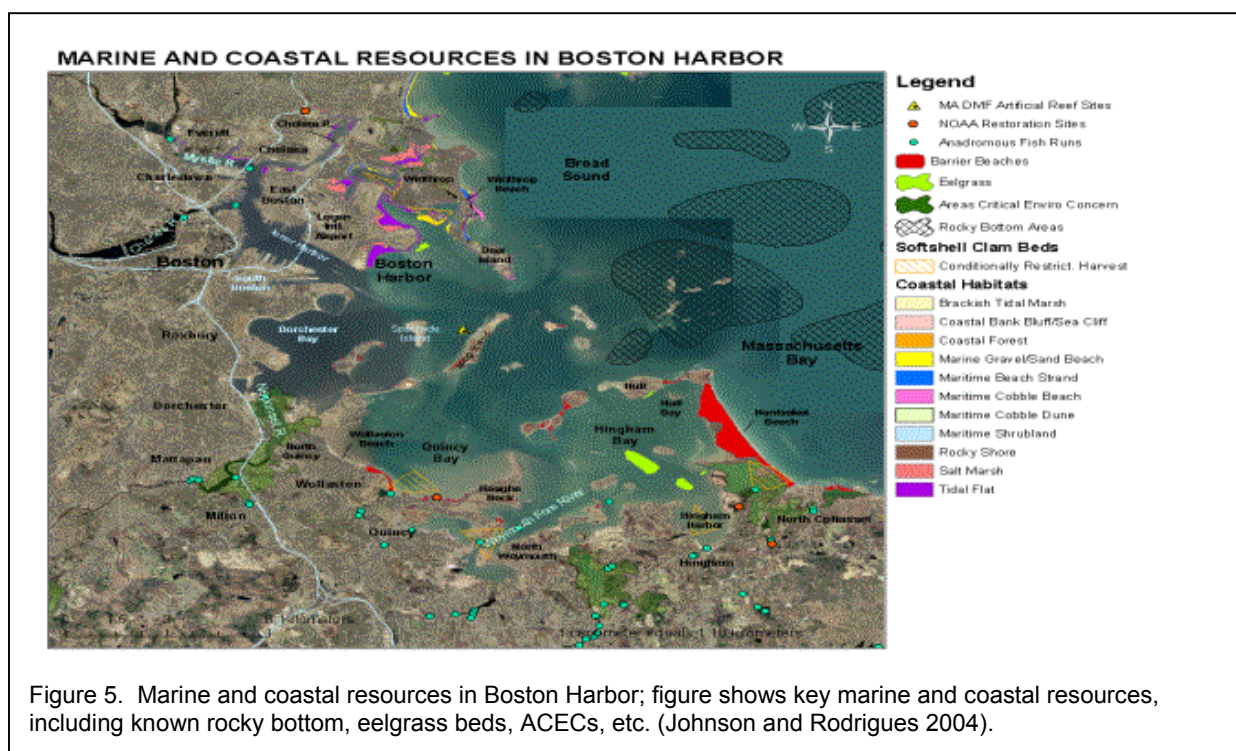


Figure 5. Marine and coastal resources in Boston Harbor; figure shows key marine and coastal resources, including known rocky bottom, eelgrass beds, ACECs, etc. (Johnson and Rodrigues 2004).

POINT SOURCE POLLUTION & HAZARDOUS WASTE SITES AROUND BOSTON HARBOR



Figure 6. Point source pollution and hazardous waste sites around Boston Harbor; figure illustrates point source pollution, hazardous waste sites, Hubline gas pipeline, cables, sewer lines, etc. (Johnson and Rodrigues 2004).

TYPES OF ACTIVITIES IMPACTING MARINE RESOURCES IN BOSTON HARBOR

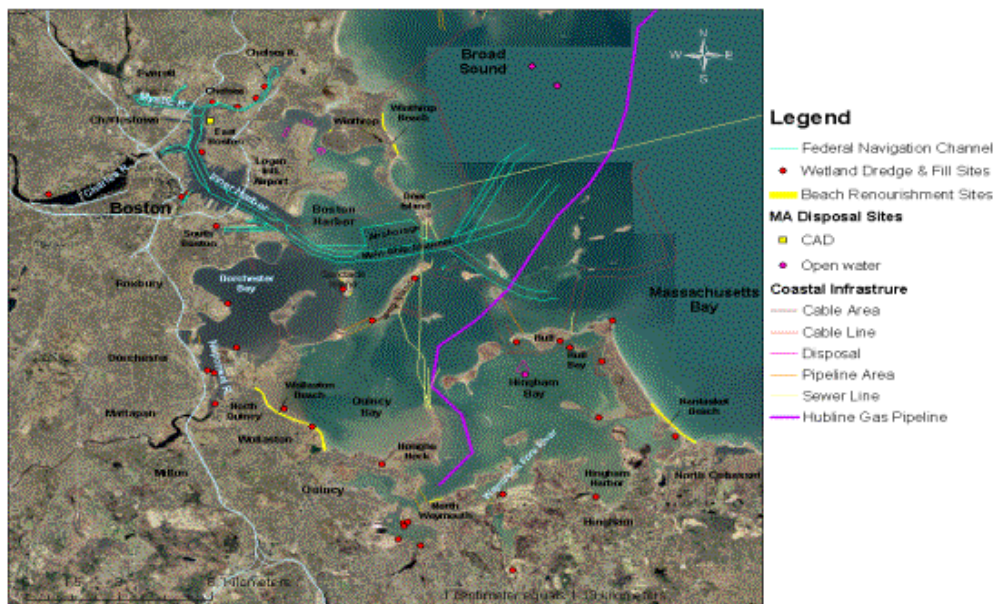


Figure 7. Types of activities impacting resources in Boston Harbor; figure shows navigation channels, wetland dredge/fill sites, beach renourishment and confined aquatic disposal locations (Johnson and Rodrigues 2004).

EMERGING ISSUES

The identified threats and examples of cumulative impacts in Boston Harbor are an overview of a complex issue. These identified impacts along with additional unidentified threats potentially influence ocean resources in Massachusetts. Massachusetts waters have always supported many human uses. In addition to the above discussed existing anthropogenic impacts, the following are a few emerging issues which we anticipate to contribute to cumulative impacts in the future:

- Energy facility development (e.g., windmills) and similar proposals to use marine environment as a means of creating renewable energy;
- Desalination plants;
- Sound pollution (including Navy, National Defense and recreational vessel sonar, dynamite used in pipeline, CAD and cable construction, boat engines, dredging/sand mining operations and exploration for oil and gas resources);
- Increasing shellfish aquaculture and fish farm development; and
- Continued construction of docks, piers, floating hotels

SUMMARY

Cumulative impacts in estuarine and marine habitats are important to consider both now and into the future to ensure environmental quality and improve the status and condition of ocean resources in Massachusetts. An understanding of the type, diversity, distribution and ecological implications of these threats can assist in the development of ocean resources management practices. A thorough ocean resources research and monitoring plan designed to evaluate natural variability and human-induced impacts in the ocean resources of Massachusetts is fundamental to understanding cumulative impacts.

Although major impacts to estuarine and marine habitat and life caused by human activities and natural processes are identified in this report, it is important to recognize that many other anthropogenic caused impacts threaten the quality of the ocean environment in Massachusetts. Cumulative impacts should be recognized while developing ocean resource management plans for Massachusetts; activities which may initially appear to be small-scale, can still prove to have substantial effects for the long-term ecological sustainability of the marine and coastal environment.

A few natural processes or global phenomena that – as an individual state – Massachusetts has little control over were identified; however, Massachusetts has a degree of control over many of the anthropogenic impacts, which can lend themselves to management by the state – which is the subject of many of the Task Force’s recommendations. The distribution of key impacts show that few areas along the Massachusetts coast remain undisturbed by human impacts, with Boston Harbor being one of the most heavily used areas. This section also noted emerging issues that are expected to become of greater importance as future management strategies are negotiated. Cumulative impacts will remain a notable challenge without a

comprehensive research and monitoring plan and guidelines to evaluate human-induced alteration to ocean resources in Massachusetts.

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